U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

15.1.5 RADIOLOGICAL CONSEQUENCES OF MAIN STEAM LINE FAILURES
APPENDIX A OUTSIDE CONTAINMENT OF A PWR

REVIEW RESPONSIBILITIES

Primary - ~~Accident Evaluation Branch (AEB)~~ Emergency Preparedness and Radiation Protection Branch (PERB)[1]

Secondary - Reactor Systems Branch (~~RSB~~SRXB)[2]

I. AREAS OF REVIEW

The Standard Review Plan (SRP)[3] Section 15.1.5 covers the review by the Reactor Systems Branch (~~RSB~~SRXB)[4] of the main steam line break (MSLB) accident outside the containment of a pressurized water reactor (PWR)[5] plant, including the response of the reactor and plant systems; the potential for fuel failure; and the effect on the core thermal margins. This Appendix A to SRP Section 15.1.5 covers the review by the ~~AEB~~ PERB[6] of the radiological consequences of the MSLB accident. The review includes the following:

1. Review of the sequence of events, as described by the applicant, with and without offsite power available, to ~~assure~~ ensure[7] that the most severe ~~case of radioactive releases has been considered,~~ calculated release of radioactive material has been identified. This determination is based on the amount of material released as well as on the resulting calculated doses;[8]

2. Review of the models and assumptions used by the applicant for the calculation of the thyroid and whole-body doses for the postulated accident;

3. Independent calculation by the staff of the thyroid and whole-body doses for the MSLB accident;

4. Comparison of the doses calculated by the applicant and by the staff with appropriate exposure guidelines, as stated in subsection II below;

5. Evaluation of the technical specifications on the primary and secondary coolant iodine activities; and

6. ~~Two cases for the~~ Determination of[9] reactor coolant iodine concentration corresponding to (a) a preaccident iodine spike and (b) a concurrent iodine spike.

Review Interfaces[10]

A secondary review is performed by the ~~RSB~~ SRXB, and the results are used by ~~AEB~~ PERB in the overall evaluation of the MSLB radiological consequence analysis. The potential for fuel failures resulting from the postulated MSLB accident is routinely evaluated by the ~~RSB~~SRXB under SRP Section 15.1.5, and the results will be provided to the ~~AEB~~ PERB as an additional source of radioactive iodine ~~activity~~[11] in the reactor coolant for consideration in the evaluation of the MSLB radiological consequences.

The review of the technical specifications is coordinated with and performed by the ~~Licensing Guidance Branch~~ Technical Specifications Branch (TSB)[12] as part of its primary review responsibility for SRP Section 16.0. The acceptance criteria necessary for the review and the methods of application are contained in the referenced SRP section.

II. ACCEPTANCE CRITERIA

The acceptance criteria are based on the relevant requirements of 10 CFR Part 100 as related to the radiological consequences of a postulated accident. The plant site and the dose mitigating engineered safety features are acceptable with respect to the radiological consequences of a postulated MSLB outside containment of a PWR facility if the calculated whole-body and thyroid doses at the exclusion area and the low population zone outer boundaries do not exceed the following exposure guidelines:

1. For an MSLB with an assumed preaccident iodine spike and for an MSLB with the highest worth control rod stuck out of the core, the calculated doses should not exceed the guideline values of 10 CFR 100.11; ~~Part 100., Section 11 (Ref. 1),~~[13] and

2. For an MSLB with the equilibrium iodine concentration for continued full power operation in combination with an assumed accident initiated iodine spike, the calculated doses should not exceed a small fraction of the above guideline values, i.e., 10 ~~percent~~%[14] or 25 mSv (2.5 rem),[15] and 0.3 Sv (30 rem),[16] respectively, for the whole-body and thyroid doses.

The methodology and assumptions for calculating the radiological consequences should reflect the regulatory positions of Regulatory Guide 1.4, ~~(Ref. 8)~~[17] except for the atmospheric dispersion factors which are reviewed under SRP Section 2.3.4.

~~Plant technical specifications are required for the iodine activity in the primary and secondary coolant system and for the leak rate from the primary to the secondary coolant system in the steam generator(s).~~ Plant technical specifications include limits for the maximum concentration of radioactive iodine permitted in the primary and secondary coolant systems and the permissible leak rate from the primary to the secondary coolant system in the steam generator(s).[18] These specifications are acceptable if the calculated potential radiological consequences from the MSLB accident are within the exposure guidelines for the above two cases.

Technical Rationale[19]

The technical rationale for application of these acceptance criteria to reviewing the applicant's analyses of transients initiated by steam system piping failures is discussed in the following paragraphs:[20]

Compliance with 10 CFR Part 100 requires that a suitable exclusion area, low population zone, and population center distance be determined for each nuclear power plant site. Further, radiation exposure criteria stipulated in 10 CFR Part 100 provide reference values to be used in the site suitability determination based on postulated fission product releases associated with accidental events.

The requirements of 10 CFR Part 100 are applicable to this section because they specify the methodology for calculating radiation exposures at the site boundary for postulated accidents or events such as loss of a reactor coolant pump. For events having a moderate frequency of occurrence, any release of radioactive material must be such that the calculated doses at the site boundary are a small fraction of the 10 CFR Part 100 guidelines. A small fraction is interpreted to be less than 10% of the 10 CFR Part 100 reference values. For the purpose of this review, the radiological consequences of any steam piping failure must include consideration of the containment, confinement, and filtering systems. The applicant's source terms and methodologies with respect to gap release fractions, iodine chemical form, and fission product release timing should reflect NRC-approved source terms and methodologies such as those contained in NUREG-1465.

Meeting this requirement provides assurance that, in the event of a main steam piping failure, radiation exposures at the site boundary will not exceed a small fraction of the reference values specified in 10 CFR Part 100.[21]

III. REVIEW PROCEDURES

The reviewer selects and emphasizes specific aspects of this SRP section as are appropriate for the particular plant. The review areas to be given attention and emphasis are determined by the similarity of the information presented in the safety analysis report (SAR)[22] to that recently reviewed on other plants and whether items of special safety significance are involved.

At the construction permit stage, there is generally insufficient information available to make meaningful radiological consequence calculations for this accident. ~~At this stage, the review is limited to a brief review of the applicant's discussion of the main steam line failure accidents to determine that there are no unusual design features that would preclude the limitation of radiological consequences by appropriate limits on coolant concentrations and primary-to-secondary system leak rate.~~ The applicant's discussion of the main steam line failure accidents is reviewed to confirm that there are no unusual design features that would render technical specification limits ineffective in controlling the radiological consequences of such events.[23] The detailed review of radiological consequences of the main steam line failure accident is done at the operating license (OL) or combined license (COL)[24] stage when system parameters are fully developed.

The standard technical specifications for the nuclear steam supply system (NSSS)[25] of each of the three PWR vendors include limits on the primary and secondary coolant activities and primary-to-secondary leak rate. These limits are used by the staff in its independent dose calculations when plant-specific technical specifications are not available. ~~If the applicant proposes to use these standard limits and the plant is one of the standard NSSS/BOP plants for which the steam line failure accident has been evaluated generically with the standard coolant activity and leakage limits, then the reviewer need not reevaluate the offsite doses from this accident provided that the atmospheric dispersion factors (X/Q values) for the site under review are lower than the limiting X/Q used in the generic review of the standard plant steam line failure.~~ The reviewer need not reevaluate the offsite doses from this accident provided (1) the plant is one of the standard NSSS/balance-of-plant units for which the steam line failure accident has been evaluated generically with the standard coolant activity and leakage limits, (2) the applicant proposes to use these standard limits, and (3) the atmospheric dispersion factors (X/Q values) for the site under review are lower than the limiting X/Q value used in the generic review of the standard plant steam line failure.[26]

The review of main steam line failure accidents at the ~~operating license~~ OL or COL[27] stage consists of the following steps:

1. Review of the applicant's descriptions of the steam line failure accident, with and without offsite power. This includes a review of the time sequence of occurrence of events.

2. Review of the applicant's description of events by the ~~RSB~~SRXB, including operator actions. Review of the sequence of events to ~~assure~~ensure that the most severe ~~case from the standpoint of release of radioactive materials and calculated doses has been identified~~ calculated release of radioactive material has been identified. This determination is based on the amount of material released as well as on the resulting calculated doses.[28]

3. Determination of primary and secondary coolant activity equilibrium concentrations. The reviewer assumes the primary and secondary coolant activity concentrations allowed by the technical specifications (SAR Chapter 16 or the standard technical specifications given in References 2, 3, or 4) as equilibrium concentrations prior to the accident.

4. Determination of iodine spiking effects. For the dose calculations the following two cases of iodine spiking are analyzed:

   (a) A reactor transient has occurred prior to the postulated MSLB and has raised the primary coolant iodine concentration to the maximum value permitted by the standard technical specifications (i.e., a preaccident iodine spike case). The primary coolant iodine concentration for this case is obtained from Figure 3.4.16-1[29] of the NSSS vendor standard technical specification ~~(Ref. 2, 3, or 4)~~[30] or from the plant-specific technical specifications proposed in Chapter 16 of the applicant's SAR, as appropriate.

   (b) The reactor trip and/or primary system depressurization associated with the MSLB creates an iodine spike in the primary system (i.e., concurrent iodine spike case)[31] (Refs. ~~5~~6 and ~~6~~7).[32] The increase in primary coolant iodine concentration is estimated using a spiking model which assumes that the iodine release rate from the fuel rods to the primary coolant (expressed in becquerels (curies)[33] per unit time) increases to a value 500 times greater than the release rate corresponding to the iodine concentration at the equilibrium value stated in the NSSS vendor standard technical specifications or from the plant-specific technical specifications, as appropriate ~~(i.e., concurrent iodine spike case)~~.

5. Evaluation of the effects of fuel failure. As a result of the MSLB accident, fuel failures can occur, releasing fission products into the reactor coolant and thus making additional activity available for release to the atmosphere. The ~~RSB~~SRXB reviews, under SRP Section 15.1.5, the effects of the MSLB on the core thermal margins and the associated amount of fuel failures, assuming that the highest worth control rod is stuck at its fully withdrawn position. The ~~RSB~~SRXB, as a secondary review branch, will inform the ~~AEB~~ PERB of the fuel failure estimate. If the MSLB accident is predicted to cause such fuel failure, a dose analysis will be performed with the corresponding iodine activity but without a concurrent iodine spike.

6. Determination of the primary-to-secondary leakage. Normal operating primary-to-secondary leakage is assumed to exist in the steam generators. The leakage rate should be the maximum allowed by the technical specifications. This value is 1 gpm[34] in the ~~STS~~ standard technical specifications[35] but may be lower, if required, because of the radiological consequences of a rod ejection accident. The leakage should be apportioned between affected and unaffected steam generator(s) in such a manner that the calculated dose is maximized.

7. Determination of iodine transport to the atmosphere. During periods of steam generator dry-out, all iodine transported to the secondary side by primary coolant leakage is assumed to be released to the atmosphere. During periods of total submergence of the tubes, the fraction of iodine released is equal to the flash fraction of the primary coolant leakage. Appropriate credit for scrubbing by the secondary coolant may also be claimed using models presented in Reference ~~7~~8.[36] Any iodine transferred to the secondary coolant system will become airborne at a rate which is a function of the steaming rate and iodine partition coefficient. An iodine partition coefficient of 100 between steam

generator water and steam phases may be conservatively assumed, unless the applicant presents reasonable evidence that the use of some other value is justified.

8. Determination of atmospheric dispersion characteristics (X/Q values). The appropriate X/Q values are determined by the assigned meteorologist in accordance with SRP Section 2.3.4.

9. Calculation of the exclusion area boundary (EAB) and low population zone (LPZ) boundary doses. The reviewer performs an independent calculation of the doses for the steam line break accident, using the two iodine concentrations in item 4 above. The breathing rates and dose conversion factors are in accordance with Regulatory Guide 1.4 ~~(Ref. 8)~~.[37]

10. Review of dose calculations. The whole-body and thyroid doses calculated by the staff and by the applicant are compared with the acceptance criteria stated in subsection II of this appendix. If the doses calculated by the staff are not within the exposure guidelines, then the staff will reduce, as necessary, any of the following plant-specific technical specifications: the primary and/or secondary equilibrium iodine concentrations, maximum primary coolant iodine activity (preaccident spike), or primary-to-secondary system leak rate.

For standard design certification reviews under 10 CFR Part 52, the procedures above should be followed, as modified by the procedures in SRP Section 14.3 (proposed), to verify that the design set forth in the standard safety analysis report, including inspections, tests, analysis, and acceptance criteria (ITAAC), site interface requirements and combined license action items, meet the acceptance criteria given in subsection II. SRP Section 14.3 (proposed) contains procedures for the review of certified design material (CDM) for the standard design, including the site parameters, interface criteria, and ITAAC.[38]

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided by the applicant and that the applicant's analysis and the staff's independent calculations support conclusions of the following type, to be included in the staff's safety evaluation report at the ~~operating license~~ OL or COL[39] stage:

The staff concludes that the distances to the exclusion area and to the low population zone outer boundaries for the (insert PLANT NAME) site, in conjunction with the operation of the dose-mitigating ~~ESF~~ engineered safety feature[40] systems, are sufficient to provide reasonable assurance that the calculated radiological consequences of a postulated main steam line failure outside the containment do not exceed (1) the exposure guidelines as set forth in 10 CFR ~~Part 100 §~~100.11[41] for an MSLB with an assumed preaccident iodine spike or for an MSLB with the highest worth control rod stuck out of the core and (2) 10 ~~percent~~%[42] of these exposure guidelines for an MSLB with an equilibrium iodine concentration in combination with an assumed accident-generated iodine spike. The results of the staff's calculations are listed in Table 15.

The staff's conclusion is based on (1) the staff review of the applicant's analysis of the radiological consequences; (2) the independent dose calculation by the staff using conservative assumptions, including atmospheric dispersion factors as discussed in Chapter 2 of this report; and (3) the (INSERT NSSS VENDOR) standard technical specifications for the iodine concentration in the primary and secondary coolant system and for the primary-to-secondary leakage in the steam generators. The staff will review the (PLANT NAME)-specific technical specifications to ~~assure~~ensure that the dose guidelines stated above are not exceeded.

At the construction permit stage, the following paragraph is included in the staff's safety evaluation report (SER):[43]

> On the basis of our experience with the evaluation of steam line and steam generator tube failure accidents for PWR plants of similar design, we have concluded that the consequences of these accidents can be controlled by limiting the permissible primary and secondary coolant system radioactivity concentrations and/or primary-to-secondary leak rates so that potential offsite doses are small. At the operating license stage, we will include appropriate limits on these parameters to be included in the plant technical specifications.

For design certification reviews, the findings will also summarize, to the extent that the review is not discussed in other safety evaluation report sections, the staff's evaluation of inspections, tests, analyses, and acceptance criteria (ITAAC), including design acceptance criteria (DAC), site interface requirements, and combined license action items that are relevant to this SRP section.[44]

V. IMPLEMENTATION

The following provides guidance to applicants and licensees regarding the staff's plans for using this SRP section.

This SRP section will be used by the staff when performing safety evaluations of license applications submitted by applicants pursuant to 10 CFR 50 or 10 CFR 52.[45] Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications docketed six months or more after the date of issuance of this SRP section.[46]

Implementation schedules for conformance to parts of the method described herein are contained in the referenced regulatory guide.

VI. REFERENCES

1. 10 CFR 100.11,~~Part 100, Section 11,~~[47] "Determination of Exclusion Area, Low Population Zone, and Population Center Distance."

2. Standard Technical Specifications for Combustion Engineering PWRs, NUREG-~~0212~~1430.[48]

3. Standard Technical Specifications for Westinghouse PWRs, NUREG-~~0452~~1431.[49]

4. Standard Technical Specifications for Babcock and Wilcox PWRs, NUREG-~~0103~~1432.[50]

5 NUREG-1465, "Accident Source Terms for Light-Water Nuclear Power Plants," February 1995.[51]

~~5~~6. R. R. Bellamy, "A Regulatory Viewpoint of Iodine Spiking During Reactor Transients," Trans. Am. Nucl. Soc., 28 (1978).

~~6~~7. W. F. Pasedag, "Iodine Spiking in BWR and PWR Coolant Systems," CONF-770708, 3-217 (1971).

~~7~~8. A. K. Postma and P. S. Tam, "Iodine Behavior in a PWR Cooling System Following a Postulated Steam Generator Tube Rupture Accident," NUREG-0409, USNRC, 1978.

~~8~~9. Regulatory Guide 1.4, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss-of-Coolant Accident for Pressurized Water Reactors."[52]

SRP Draft Section 15.1.5
Attachment A - Proposed Changes in Order of Occurrence

Item numbers in the following table correspond to superscript numbers in the redline/strikeout copy of the draft SRP section.

Item	Source	Description
1.	Current PRB abbreviation	Changed Accident Evaluation Branch to Emergency Preparedness and Radiation Protection Branch (PERB).
2.	Current SRB abbreviation	Changed RSB to SRXB (global change for this section).
3.	Editorial	Defined SRP.
4.	SRP-UDP format item	Changed RSB to SRXB (global change for this section).
5.	Editorial	Defined PWR.
6.	SRP-UDP format item	Changed AEB to PERB (global change for this section).
7.	Editorial	Replaced "assure" with "ensure" (global change for this section).
8.	Editorial	Revised sentence for clarity, precision, and to make it consistent with the revised wording of REVIEW PROCEDURES, step 2.
9.	Editorial	Revised sentence for clarity, precision, and to achieve parallel construction.
10.	SRP-UDP format item	Added "Review Interfaces" to AREAS OF REVIEW to describe how PERB coordinates the review of the MSLB accident outside the containment of a PWR plant with other NRR branches.
11.	Editorial	Replaced "iodine activity" with "radioactive iodine" for clarity and precision.
12.	SRP-UDP format item	Changed Licensing Guidance Branch to Technical Specifications Branch (TSB).
13.	SRP-UDP format item	Converted citation for Code of Federal Regulations to proper format and deleted unnecessary reference designation.
14.	Editorial	Used "%" for "percent."
15.	SRP-UDP format item	Metric conversion. Converted 2.5 rem to 25 mSv.
16.	SRP-UDP format item	Metric conversion. Converted 30 rem to 0.3 Sv.
17.	Editorial	Deleted unnecessary reference identification.
18.	Editorial	Sentence revised for clarification and precision.
19.	SRP-UDP format item	Added "Technical Rationale" to ACCEPTANCE CRITERIA and presented in paragraph form.

Item	Source	Description
20.	SRP-UDP format item	Added lead-in sentence for "Technical Rationale."
21.	SRP-UDP format item	Added technical rationale for 10 CFR Part 100.
22.	Editorial	Defined SAR.
23.	Editorial	Sentence revised for clarity and precision.
24.	SRP-UDP format item	Added the abbreviation (OL) and a reference to combined license (COL) reviews.
25.	Editorial	Defined NSSS.
26.	Editorial	Sentence revised for clarity. Defined BOP.
27.	SRP-UDP format item	Added the abbreviation "OL" in place of "operating license" and a reference to the COL review stage.
28.	Editorial	Revised sentence for clarity, precision, and to make it consistent with the revised wording of paragraph I.1.
29.	Integrated Impact No. 791	Revised figure number for current revision of STS.
30.	Editorial	Reference numbers for the NSSS vendor standard technical specifications were provided in the previous paragraph and need not be repeated.
31.	Editorial	Repositioned parenthetical phrase that was misplaced at the end of the paragraph.
32.	Editorial	Renumbered reference citations.
33.	SRP-UDP format item	Metric conversion. The becquerel is the preferred metric unit, replacing the curie.
34.	SRP-UDP format item	The current STS does not present the metric equivalent of the primary to secondary maximum allowable leakage rate of 1 gpm. It is recommended, in this instance, that metrication be postponed until the conversion has been made in the STS.
35.	Editorial	Defined "STS" as "standard technical specifications."
36.	Editorial	Renumbered reference citation.
37.	Editorial	Deleted unnecessary reference identification.
38.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.
39.	SRP-UDP format item	Added the abbreviation "OL" in place of "operating license" and a reference to the COL review stage.
40.	Editorial	Defined "ESF" as "engineering safety system."
41.	SRP-UDP format item	Converted CFR citation to proper format.
42.	Editorial	Used "%" for "percent."

Item	Source	Description
43.	Editorial	Provided "SER" as initials for "safety evaluation report."
44.	SRP-UDP Format Item, Implement 10 CFR 52 Related Changes	To address design certification reviews a new paragraph was added to the end of the Evaluation Findings. This paragraph addresses design certification specific items including ITAAC, DAC, site interface requirements, and combined license action items.
45.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard sentence to address application of the SRP section to reviews of applications filed under 10 CFR Part 52, as well as Part 50.
46.	SRP-UDP Guidance	Added standard paragraph to indicate applicability of this section to reviews of future applications.
47.	SRP-UDP format item	Converted CFR citation to proper format.
48.	Integrated Impact No. 791	Updated reference to NSSS Standard Technical Specifications.
49.	Integrated Impact No. 791	Updated reference to NSSS Standard Technical Specifications.
50.	Integrated Impact No. 791	Updated reference to NSSS Standard Technical Specifications.
51.	Integrated Impact 1369	Added NUREG-1465 to the list of references and renumbered subsequent references.
52.	Integrated Impact No. 792	No change in this SRP section is required by the integrated Impact. However, the industry standard (ICRP 2) referenced in Regulatory Guide 1.4 is outdated. A comparison of ICRP 2 with the current ICRP 30 should be performed to support an update of the citation. IPD 7.0 Form No. 15.6.5.a-3 recommends such a comparison.

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Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
791	Consider updating references to the standard technical specifications (STSs).	Subsection III, REVIEW PROCEDURES, paragraph 4(a) Subsection VI, REFERENCES, References 2 through 4
792	Consider adopting the current industry standard (ICRP 30) that provides standard breathing rate and dose conversion factors for use in radiological dose calculations.	No changes were made
1369	Revise the REFERENCES to include a reference to the currently-approved analytical methods and computer codes applicable to ABB-CE 80+ plants.	Subsection VI, REFERENCES, Reference 3